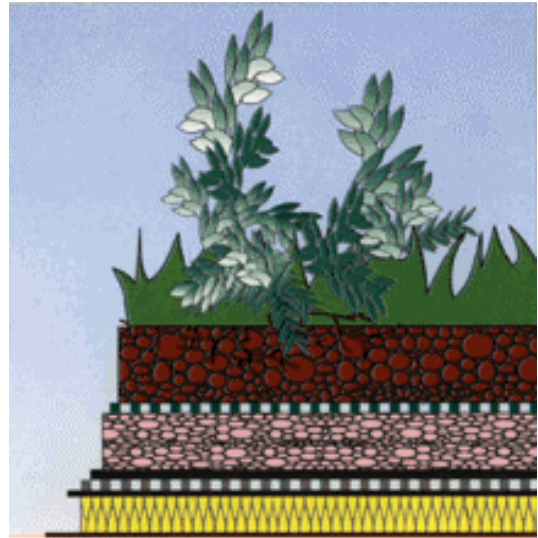


CONSTRUCTION

The construction and success of eco-roofs depends on the specific needs and conditions of a site. Wind, temperature, moisture regime, and sun exposure can vary considerably from project to project. Eco-roofs are generally comprised of five or six components including, from the roof deck up: a waterproof membrane; an optional layer of insulation or a protective layer; a drainage layer; the growing medium, also referred to as ‘substrate’; vegetation; and in some cases an irrigation system (figure 5.1). Many of the problems associated with green roofs stem from the faulty installation of one or more of these layers and/or careless maintenance practices. In no other landscape element is the relationship between design, construction detailing, and long-term maintenance so interdependent.



*5.1 Cross section of a typical green roof
(Roofscapes Inc.).*

Over the past 30 years, a number of roofing membrane companies have designed complete intensive and extensive systems, including specialized drainage layers, scientifically formulated, lightweight growing mediums, and growing mats impregnated with seeds. The following portion of the thesis looks to review, at a relatively broad level, the components of eco-roof construction. This section should not be considered a comprehensive review of the systems presently available, but rather a general synopsis of the materials and conditions typically required.

BUILDING CODES AND REGULATIONS

Unlike Germany and several other European countries, which strictly regulate the manufacturing of materials used for green roofs, as well as the construction process, neither the *National Building Code of Canada, 1995* or the *Building Code of British Columbia, 1998* discuss roofing materials beyond those used in conventional membrane and roof assemblies. These building regulations, as well as those in the *Vancouver Building By-law, 1999*, merely require that the selected materials meet performance standards and provide the necessary protection from precipitation.

The roofing membrane guarantee issued by the Roofing Contractors Association of British Columbia (RCABC) also does not preclude the installation of green roofs. So long as the membrane's manufacturer guarantees their work and the building owner accepts responsibility for and the associated costs of removing the green roof in the event of membrane failure, the RCABC will guarantee the roof (Altizer 2000).

ROOF SLOPE

Contrary to popular belief, and as evidenced by historical examples, eco-roofs do not require low-slope (often referred to as flat) roofs as do conventional roof gardens but may be installed on roofs with slopes of up to 45 degrees. A low slope is desirable, though, for both intensive and extensive systems in order to slow the flow of water from the roof. Pitched roofs require special considerations including raised grids to prevent the substrate from slipping, and for slopes greater than five degrees, it might be necessary to compensate for rapid runoff by increasing the retention capacity of the substrate. As low-slope systems comprise the majority of green roof installations, the following chapter assumes minimal slopes in its discussion.

STRUCTURAL/LOAD BEARING

Developers and contractors often regard the production of roof gardens with apprehension because of the extra weight that they add. Structural engineers divide loads into two categories: dead loads and live loads. The *dead load* refers to the weight of the roof structure itself and any permanent functional elements. The *live load*, on the other hand, includes elements such as human occupants, snow, rain, maintenance equipment, and other items of a transient nature. Regardless of how light a green system may be, the provision must be made for both the weight and dimensions of equipment and material which may be used at various stages of construction and maintenance of the roof (Nature Conservancy Council 1990, 10).

The first issue concerning loads is whether a building is being designed for a green roof or is being retrofitted. In new construction, the roof's structural system can be designed from the outset as required with relatively little additional cost (Taylor 2000). Retrofitting, on the other hand, can be more difficult and quite costly. Architects and engineers generally design buildings to meet regionally specific codes, with little allowance for additional roof loading. As such, retrofitting, as well as structural redesign prior to construction, can increase costs substantially. The Mountain Equipment Co-op's 903 m² (9,720 ft²) green roof in Toronto required structural redesign to accommodate its eco-roof. Labour and materials for the roof cost \$115,000 (\$12 sq/ft) however, the structural upgrade (redesign) of \$55,000 added another \$5 per square foot (Peck, et al. 1999, Appendix II).

The fundamental requirements for green roof design include achieving a maximum planting effect using minimum organic support and spreading the weight load over a wide area (Funke 1992, 46). In concept, eco-roofs are lightweight, modern versions of the sod roofs of Scandinavia. Proponents of eco-roofs assert that these system's light weight generally requires

little additional load-bearing capacity from most buildings' structural systems, and in some cases may be installed on existing buildings with no structural modification. There are a number of green roofing system manufacturers that suggest that extensive landscape systems need not be heavier than the gravel covering used on some roofs. According to Kölb's article in *Anthos*, a German landscaping and landscape architecture journal, the majority of low-slope roofs in Germany are covered with gravel (approximately 5 cm [2 in]), which has a load of about 100 kg/m^2 (20 psf) (5). Using this load as the guideline for an extensive system, Kölb suggests that many gravel roofs might be greened, without additional load reserves. While studies have shown it possible to replace the gravel layer of gravelled flat roofs with a green roof system equivalent, much of this research relates specifically to European building standards and load requirements. When applied to North America, gravel protected or ballasted roofs use 1-5 cm (0.4-2 in) of gravel, depending on the membrane, constituting a load of approximately 20-100 kg/m^2 (4-20 psf). This makes the widespread replacement of gravel with eco-roofs far less feasible. There are however, foam systems, developed for low-cost green roofs, that weigh as little as 25-30 kg/m^2 (5-6 psf) with maximum water uptake, as well as pre-planted roofs, with small meadow flowers and grasses or pre-turfed roofs with loadings of 82 kg/m^2 (17 psf) and 66 kg/m^2 (13.5 psf) respectively. The latter can be compared to concrete roofing tiles, which have a dead load of 70 kg/m^2 (14 psf) (Nature Conservancy Council 1990, 15; Vale 1991, 149).

COST

Capital

Costs for creating and maintaining an extensive green roof are generally much less than those for an equivalent area of intensive roof garden. Some estimates suggest that costs could be

reduced by 50 percent or even as much as 80 percent by using an extensive rather than intensive system (Johnson and Newton 1996, 72). This reduction is attributed to the reduced need for structural reinforcement, smaller quantities of materials, and fewer maintenance requirements.

There is some disagreement, though, as to the average capital costs of eco-roofs. Johnson and Newton and Steven Peck assert that if planned from the outset, they can be included in the design of a building at little or no extra capital costs (Johnson and Newton 1996, 72; Peck, et al. 1999, 16). While costs associated with additional loading requirements might prove minimal if included in the initial planning of the building, the application of several layers of materials above and beyond a conventional system inevitably creates a difference in the ultimate cost of the roof. Where a conventional roof will range between \$1.50 and \$10 per square foot depending on the roofing material, the eco-roofs manufactured and installed by green roofing companies typically range between \$8 and \$20 per square foot, depending on the system and more importantly the vegetation that is used. This is two to four times the cost of a middle-range conventional roof per square foot.

According to Marie-Anne Boivin, the cost of the Sopranature system, manufactured by Soprema Canada, varies depending on the type of vegetation desired and the amount of work required to install the system. Initial costs usually fall between \$8 and \$13 per square foot (Tynan, 1998, 2). The patented built-up systems produced by membrane companies such as Soprema, Erisco Bauder, Optima, Garland are more expensive than do-it-yourself versions as they include layers—soil mixtures, drainage mats, etc.—specifically developed (and marketed) for the roof. While they are convenient, systems of comparable quality can be designed and installed by qualified professionals for considerably less.

A rough cost-analysis done by Katrin Scholz-Barth, Director of Sustainable Design for the HOK Planning Group in Washington, D.C., on a theoretical eco-roof illustrates how a do-it-yourself system might compare to a conventional roof. Scholz-Barth suggests that an extensive system might cost only about one third more than the same roof without vegetation. Scholz-Barth notes that if the potential energy savings from the insulation and a longer lifespan for the roof are taken into account, the annual cost over the lifetime of a green roof may be only half that of a conventional assembly. A conventional roof costing \$100,000 with a lifetime of 24 years has an annual depreciation of \$4,200. A similar greened roof would cost about \$135,000 (material costs plus installation), last about 36 years and provide an energy savings of \$70,000, giving an annual depreciation of \$1,800 (Port Phillip EcoCentre; Scholz-Barth 2000). While the above figures do not address the issue of roof replacement, assuming no complications arise and given the current lifespan of buildings, a structure would, more than likely, be taken down before the eco-roof would need to be replaced. It is important to note, though, that if the eco-roof required replacement, as in the case of membrane failure, it would be considerably more costly than a conventional roof. Regardless, for developers who are looking to build and sell quickly, even a nominal increase in the initial price can be seen as a barrier unless they feel it will make the property more marketable.

Maintenance

Conventional roof maintenance generally entails annual inspection of the membrane, and in particular locations of any projections through the membrane such as ventilation and exhaust stacks or HVAC equipment, as well as edge details. This typical maintenance of the membrane becomes essentially impossible after installation of the eco-roof. Great care must be taken in

both the selection of roofing materials and the construction of the system, as problems prove exceptionally difficult to find and costly to repair compared to conventional roofs (Crocker 1986, 7).

Maintenance costs for the vegetated portion of a green roof vary in accordance with the objectives of the project. Eco-roofs are ideally designed to require little maintenance, perhaps watering during severe drought and the removal of tree seedlings, autumn leaves, and the occasional weed several times a year (Johnson and Newton 1996, 70; Tynan 1998, 2). A low-maintenance landscape is best achieved through a naturalistic approach. Less formal and more naturalistic gardens require less attention, ultimately reducing maintenance costs. Flower-rich meadows thrive on nutrient-poor soil whereas traditional lawns require periodic additions of fertilizer. The grass on the visitors' centre at Martin Mere in England is not mown but rather allowed to grow and die back naturally each year. The only management consists of occasionally weeding out invasive plants such as ragwort and thistle (Johnson and Newton 1996, 71). The maintenance on France's largest expanse of roof greening, the 6,503 m² (70,000 ft²) meadow on the international school complex of Lyon-Gerland, has so far been limited to the annual removal of dried vegetation (Osmundson 1999, 33).

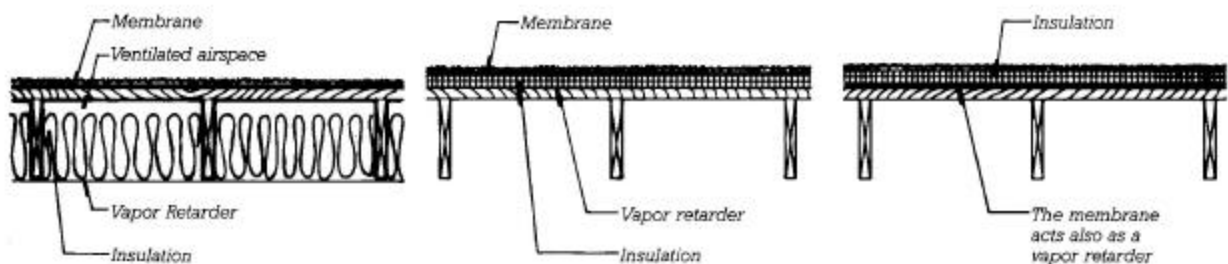
There are those who feel, though, that regardless of the type of green roof used, in a closed system, maintenance requirements are the same if not more than those landscapes at grade. Neglect can prove detrimental to the survival of a green roof. The most common causes of plant failure in roof gardens are moisture stress, deoxygenation when the drainage fails, or nutrient stress when plantings don't have adequate fertilizer (Port Phillip EcoCentre). The implementation of vegetation free zones can help facilitate maintenance. These zones improve fire safety and roof drainage; reduce the development of undesired shoots; ease the inspection

and repair of the edge connections in the roof system; and provide footpaths for vegetation maintenance.

Designers often underscore accessibility of the roof to maintenance personnel. For even modest maintenance requirements, special care must be taken to insure ready access for landscapers, gardeners and their respective equipment. While some green roofs have been in place for 50 and 60 years without requiring major repairs or replacement of soil or plantings, there is always the possibility that these or other elements may need addressing. Vancouver Public Library's green roof was originally designed to require little or no maintenance, irrigation or fertilizing, however for at least a year now VPL gardeners have needed to tend to it weekly to deal with weeds, losses in soil volume, and deteriorating plant quality. Approximately 75 percent of the library's monthly gardening fee (roughly \$1,500) is spent on the roof alone. The design of the building has made this maintenance difficult, as access to the roof is extremely awkward and somewhat dangerous (Anonymous 2000).

LAYERS

A green roof consists of several layers of materials. The selection and installation of these layers usually falls under the responsibility of the project architect, in consultation with a structural engineer, landscape architect, roofing contractor and the client. The sequence of the



5.2 Low-slope roof with insulation placed in three positions. Left: **cold roof construction**, insulation is placed below the roof deck with a ventilated airspace in between. Middle: **warm roof construction**, insulation is installed between the deck and membrane. Right: **protected membrane roof (inverted)**, in which the insulation laid above the membrane. (Allen 1999. 569)

layers can vary depending on the construction of the building. Cold, warm, and inverted (protected membrane roof [PMR]) roof construction can be used with eco-roofs, however the first two are more common (figure 5.2). The following discussion assumes the insulation is below the membrane and looks at those layers typically used in green roof construction.

Membrane/Water Proofing

The waterproof membrane layer should ideally be flexible, have good tensile strength, and be easy and efficient to join. Three coats of mastic asphalt and felts (alternately known as a built-up-roof [BUR]) form the most common construction used in Britain, however in Canada and the U.S. the most frequently used materials include reinforced PVC, EPDM, or modified bituminous material (SBS). While asphalt is an organic material and therefore subject to decomposition, there are 60-year-old green roofs constructed atop BUR's—Derry & Toms in London (1938), the Rockefeller Center in New York (1936), and Union Square in San Francisco (1942)—that have had no problems with leaks or other membrane failures (Osmundson 1999, 158).

Close supervision of workmanship is vital to avoiding defects that will be hidden by the soil. Particular care must be taken to ensure a good seal around any penetrations, which should be avoided whenever possible. In addition to roof penetrations, structural movement joints are likely points of failure and no planter or roof garden should be designed so that the joint is covered by soil. The membrane should be tested prior to the installation of other layers by plugging all rainwater outlets and then flooding the roof.

Protection

There is often concern that the roots of the plants might penetrate the roof membrane. While Scrivens argues that roots cannot 'drive' through a continuous layer of waterproof

membrane (Scrivens 1982, 76), it is advisable to protect any membrane against accidental damage, particularly physical damage during construction and from future gardening. The simplest form of protection involves placing paving slabs (although not usually appropriate for single-ply membranes), protection board, or a protective cement sand screed directly on the membrane (Scrivens 1982, 76). Extensive roofs often have a layer of PVC as protection against the unlikely penetration of roots. The PVC layer is then covered with a layer of felt to help anchor other layers and protect it from mechanical damage (Johnson and Newton 1996, 57). An advantage of an inverted system is that the insulation above the membrane can also act as protection.

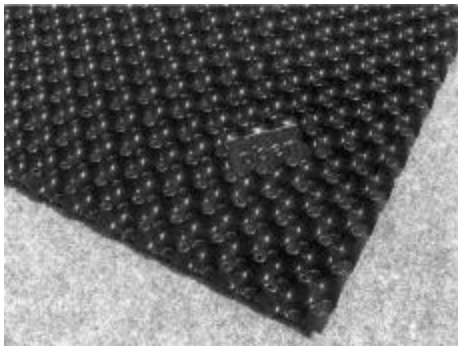
Drainage

Appropriate drainage constitutes a vital component of green roof construction. If the moisture content in the substrate remains too high, then there could be a danger of root disorders (i.e. root rot) due to the activities of plant pathogens (Scrivens 1982, 77). Two approaches to the drainage layer are as follows:

1. The roof is sloped to drain naturally. Water percolates into the soil and then through a granular base material. Certain extensive green roofs will not need a drainage layer if the roof slope is five degrees or more and the vegetation does not exceed 25 cm (10 in) in height (Johnson and Newton 1996, 58).
2. Retain water on the roof using a half-hydroculture system, which involves partial saturation. Half-hydroculture systems require considerably less irrigation, as rainwater is retained over the main body of the roof; it rises up through the planting medium via capillary action. Optima, one of the most widely used systems in Europe, contributes up to 150 kg/m² (31psf) to the live load (Scrivens 1982, 77; Osmundson 1999, 181).

A variety of materials and depths can be used for the drainage layer depending on how little or how much water is to be retained on the roof. The first drainage materials used in modern times consisted of pebbles, broken rocks, and crushed brick. More recently, drainage

materials have included LECA (light expanded clay aggregate), pea gravel, plastic foams, and even old tennis balls (Scrivens 1982, 78; Nature Conservancy Council 1990, 18). In tests at Veitshöchheim, apart from a relatively heavy gravel layer, porous materials from lava, and clay granulates proved quite effective at storing 30-40 percent of their volume in water (Kölz 1986, 6). Woven thread drainage mats are an option when water retention is not necessary or desirable. The mats contribute virtually negligible weight to a system, and give an additional mechanical protection to the protective membrane.

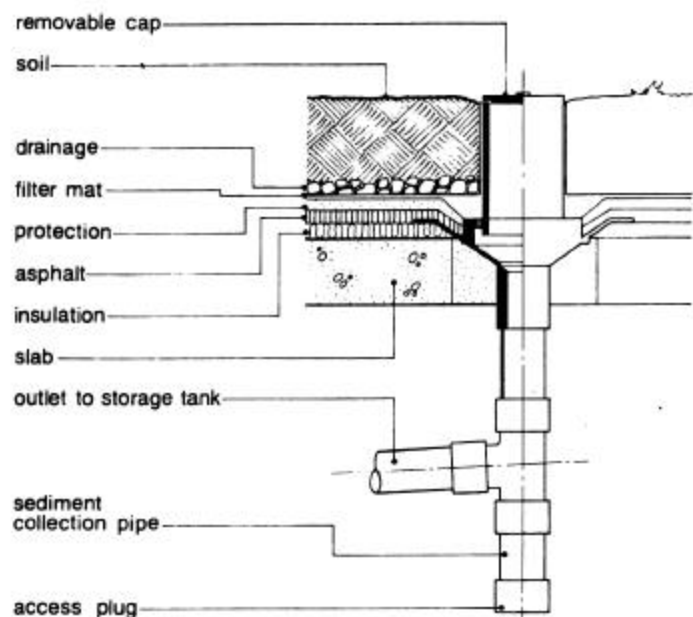


5.3 Premoulded drainage layer manufactured by Zinco (Zinco GmbH 1998).

A number of speciality drainage products have been developed in the past 30 years, including a variety of premoulded synthetic elements (Hendricks 1994, 23) (figure 5.3). Plastic foam materials are popular in Germany, Holland, and Belgium where they have an expected life span of at least 25 years and can retain up to 80 percent of their volume in water.

Regardless of the system used, carefully planned drainage points will be needed. While some people feel drains can be either totally hidden below the substrate (figure 5.5) or visible, to readily facilitate maintenance, Hendricks insists that it is essential that they are recognizable and accessible from the

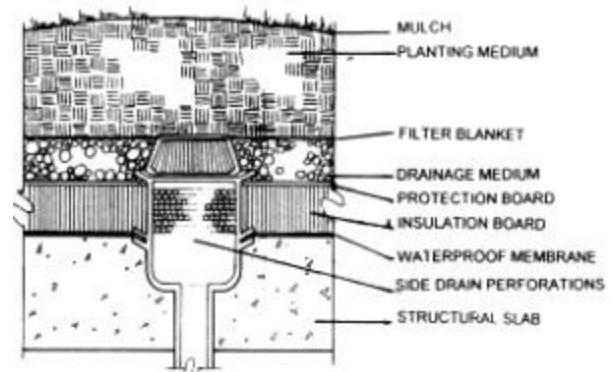
5.4 Sectional elevation of a specially designed outlet used at Gateway House in London. It drains at membrane level and can be accessed above and below (Scrivens 1980, 446).



top (figure 5.4). He notes that they should be fitted with a basket construction and cleaned at least every season (Hendricks 1994, 23). Drain design should permit water “to flow into the top at ground-surface level as well as through the sides of the drain below the surface” (Osmundson 1999, 167). This allows water runoff from the surface and subsurface drainage layer. Great care should be given to the placement of these

drainage points, and all outlets should have protective filters to stop soil from being washed down (Scrivens 1982, 78; Scrivens 1980, 445).

In order to drain water properly, it is of vital importance that the substrate has a slope of at least 1:50 (2%) with 1:25 (4%) preferred. The



5.5 Section of drain placed below the substrate (Osmundson 1998, 167).

drainage capacity must increase closer to the actual drains, and it is important to install large quantities of drainage material along the eaves and near the outlets (Hendricks 1994, 23).

Filtration

Water, passing through the planting medium to the drainage system, often carries with it bits of soil, mulch, and plant debris. If this water is not filtered, not only will valuable planting medium be lost to the building’s drainage system, but also the drains themselves can become clogged. Traditionally, this filter layer has consisted of a glass fibre mat up to 50 mm thick. This layer was then covered with a 50-mm layer of peat in order to improve filtering and the storage of moisture. With the introduction of more durable filtration materials, such as polypropylene and polyethylene fibre mats, this peat layer is no longer necessary (Scrivens 1982, 78). The filter layer must be installed carefully, with overlaps of at least 10 cm (4 in). It must be

folded up along all vertical edges, just above the top of the substrate, and finished with a strip of self-adhering bitumen membrane (Hendricks 1994, 23).

Substrate/Growing medium

The soil used for green roofs remains one of the least understood elements of the system. The special needs and conditions of these landscapes, which require strong, light, long lasting, stable, and inexpensive soil, can be confusing to the designer. In the search for appropriate growing media, some European systems have eliminated soil altogether. Climate, location, and the prospective plant species all influence soil selection (Johnson, J., Newton, J., 1996). Traditional substrate material, topsoil mixed with such materials as expanded polystyrene, 'LECA', perlite (a variety of obsidian), bark, or peat, has not proved particularly successful due to infestations of weed seeds (Kölz 1986, 8).

Plants appropriate for extensive roof systems tend to favour nutrient poor soils, therefore materials that improve the soil structure without enriching it perform best: bark, leaf mould, perlite, etc. (Port Phillip EcoCentre). A bare bones approach involves using sand, covered with a porous erosion-control fabric, and planted with stonecrop, a variety of sedum used in Berlin (Johnson and Newton 1996, 61). In Europe seed mats, foam substrates and drainage mats have been developed for low-cost, low-weight, roof planting (Nature Conservancy Council 1990, 20). Regardless of the hardiness of the plant, though, correction of nutrient deficiencies is extremely important. Certain species may require the addition of composted material, or the equivalent, for extra nutrients.

Low-maintenance, extensive systems rely not only on the substrate's capacity for water storage but also its permeability. The ideal soil creates unfavourable conditions for undesirable plants, as well as provides an optimal growing medium for the specific species to be planted.

Given the potentially conflicting effects of these conditions, one is unlikely to fulfil all the requirements (Kölz 1986, 8).

While soil depth can be as little as several centimetres, it is generally desirable to have as large a volume and depth as possible to contribute to wind stability and offset high drying rates (Port Phillip EcoCentre). Boivin and Challies recommend that the minimal substrate thickness (5 cm) used for extensive systems in Europe be increased to 8 cm (3 in) in northern regions, in order to minimize winter damage. Studies by Marie-Anne Boivin, while at the Horticultural Research Centre at Laval University in Quebec City, found that there was less winter damage in plants grown in 10-15 cm (4-6 in) of substrate compared to 5 cm (2 in). Deeper substrates (15 versus 5 cm) also proved beneficial during the summer months, resulting in a general increase in growth (Boivin 1997, 379). Thicker substrates provide greater volume in which plants can expand. This enables root systems to better establish themselves, resulting in more extensively developed aerial systems and the increased ability to resist adverse weather conditions (Boivin 1997, 380).

Roofs with higher than usual exposure often elicit concern about the stability of the substrate. If the planting medium is particularly sandy or peaty, and allowed to become too dry, then wind erosion may occur. Soil movement due to wind and/or rain, however, is generally minimal (Scrivens 1982). Over time, the substrate will experience losses in volume not only due to natural settling processes, but also through the removal of material during normal maintenance. Substrate mixtures with higher organic content tend to suffer a further reduction in volume through mineralization (the breakdown of the organic compounds) (Kölz 1986, 8).

Vegetation

One of the greatest challenges of growing plants on top of a structure comes from the landscape's high degree of exposure. The natural environments that most closely match roof garden situations are coastal plant communities (Port Phillip EcoCentre).

Growing Conditions

Wind—Wind has a drying effect on plants and soils, and can also erode the substrate, particularly before ground cover becomes established. Strong winds can uproot or damage vegetation that has not been adequately protected (Johnson and Newton 1996, 51). It is not uncommon for wind speeds at roof level to be more than double those experienced at grade (Scrivens 1982, 74). Wind can sometimes be moderated using the configuration of the roof in the careful placement of mechanical equipment, vertical lift units, parapet walls, or other building projections (Johnson and Newton 1996, 51).

Temperature—While preliminary readings indicate that it is common for winter soil temperatures of a roof garden to be at least 5°C if not 10°C higher than those in the surrounding landscape, thin soils on the roof tend to freeze more easily than deeper soils on the ground (Scrivens 1982, 75). The opposite effect occurs during the summer when rooftop soil temperatures can be up to 5°C higher. Temperatures can also vary across a roof. Summer air temperatures have been found to be 1-5°C higher on the south slope of the roof, resulting in a warmer substrate. In the winter, though, temperatures were similar across the roof regardless of slope (Johnson and Newton 1996, 52).

The building's internal climate also affects rooftop vegetation. 'Bottom heat' from a building can, on the one hand, cause plants to come into leaf and to flower several weeks before

the same plants at ground level, as well as extend the growing season. On the other hand, though, it can have a negative effect on plants normally dormant during the winter.

Moisture—Due to thin substrates and increased exposure, there is often rapid fluctuation between saturation and drought. Water loss is a particular concern between May and September. During these months some form of artificial irrigation may be needed. The need for irrigation can be modified, to some extent, for extensive green roofs by planting drought resistant species, or by incorporating rainwater-fed water storage sumps at roof level in the form of tanks or open pools (Johnson and Newton 1996, 52).

Plants

Through studies of spontaneous vegetation on unplanned green roofs, a picture of suitable plants for extensive systems begins to emerge. Appropriate species include a vast array of native and traditional garden plants. Native species, adapted to the local climate and conditions, typically require less maintenance—rarely need fertilizers, prove less susceptible to pest attack and drought, and generally require less management—and prove better



(Zinco GmbH 1998)

able to provide the food needed by wildlife. Turf and vegetation from wasteland areas (sites designated for destruction through development) and those covered with low-growing ruderal (a plant that grows on waste land) vegetation can provide suitable roof coverage. Mosses are particularly favourable as they easily cover large areas, store moisture, survive drought, add little weight to the roof, have minimal nutrient requirements, display a good tolerance of pH levels and are tolerant of a wide range of light levels (Johnson and Newton 1996, 64-66). Other plants appropriate for extensive systems include:

- Succulents and other ‘opportunists’ that create roof gardens requiring minimal maintenance.
- Alpine species, as they are resistant to wind damage and can flourish in shallow soils.
- Climbing plants, which are lightweight, cover large areas, and whose roots take up little space (Nature Conservancy Council 1990, 23).

Irrigation

Easy access to an irrigation source is needed for every green roof, even if only for initial watering or during periods of severe drought. The provision of irrigation, whether it is a system installed on the roof or a simple garden hose and sprinkler unit run from below, involves additional costs (both in capital and in maintenance) above and beyond basic green roof installation. This potential need for irrigation is a particularly important consideration for those regions with limited water resources, or where water usage charges apply.

While extensive green roofs generally do not require irrigation, except under prolonged dry conditions, their inability to access groundwater and high exposure makes evapo-transpiration losses considerably higher than at ground level. Selecting plants that tolerate arid conditions reduces the system’s dependence on irrigation. Many plants have growth forms and other means of protection for surviving prolonged dry spells. Plants generally have low growth forms and a high root-to-shoot ratio when moisture is limited, and may stop growing in the summer until rain returns in the autumn. Both succulents and mosses lie dormant when water becomes scarce.

One of the most reliable irrigation control devices for roof gardens is the use of moisture sensors in the substrate. These are pre-programmed to operate a solenoid valve and irrigate once the soil dries out to a given value (Port Phillip EcoCentre). Whether the irrigation system is manual, or partially or fully automated, the value of a moisture-sensing device such as a tensiometer cannot be overstated (Nature Conservancy Council 1990, 12).

CONCLUSION

The number and variety of green roofing systems and materials available today, as well as their respective costs, can be somewhat overwhelming and confusing. The above chapter only briefly reviews the fundamental components of eco-roof construction. Ultimately, the selection of materials relies on the specific characteristics, limitations, and objectives of the project. It is imperative that great care be taken in selecting and installing the materials. Sixty-year-old, problem free rooftop gardens do exist, however others of more recent construction have failed. Poor workmanship and damage during construction can compromise the best of intentions. Constant inspection, during the roof's installation, by knowledgeable consultants—a representative of the membrane's manufacturer, a roofing consultant, a landscape architect, etc.—is of the greatest importance to the successful performance of the roof. In the next chapter, the thesis will discuss what role well designed and constructed eco-roofs might have in Vancouver and the surrounding region